Potential Impact of Energy Efficiency Policies in U.S. Industry: Results from the Clean Energy Futures Study

Ernst Worrell and Lynn Price, Lawrence Berkeley National Laboratory

ABSTRACT
Scenarios for a Clean Energy Future (CEF) studied the role that efficient clean energy technologies can play in meeting the economic and environmental challenges for our future energy supply. The study describes a portfolio of policies that would motivate energy users and businesses to invest in innovative energy efficient technologies. On the basis of the portfolios two policy scenarios have been developed, i.e. a moderate scenario and an advanced scenario. We focus on the industrial part of the CEF-study. The studied policies include a wide scope of activities, which are organized under the umbrella of voluntary industrial sector agreements. The policies for the policy scenarios have been modeled using the National Energy Modeling System (CEF-NEMS). Under the reference scenario industrial energy use would grow to 41 Quads in 2020, compared to 34.8 Quads in 1997, with an average improvement of the energy intensity by 1.1% per year. In the Moderate scenario the annual improvement is about 1.5%/year, leading to primary energy use of 37.8 Quads in 2020, resulting in 10% lower CO_2 emissions by 2020 compared to the reference scenario. In the Advanced scenario the annual improvement increases to 1.8% per year, leading to primary energy use of 34.3 Quads in 2020, and 29% lower CO_2 emissions. We report on the policies, assumptions and the results for industry.

Introduction

The industrial sector is extremely diverse and includes agriculture, mining, construction, energy-intensive industries, and non-energy-intensive manufacturing. In 1997, the industrial sector consumed 35 Quads of primary energy, accounting for 37% of the primary energy consumed in the U.S. that year. Energy-intensive industries are still the largest energy users, although the share of light industries has grown over the past few years. Carbon dioxide emissions from industrial energy use and process emissions from cement manufacture were 494 MtC, accounting for 33% of total U.S. CO_2 emissions in 1997. Some industries also emit process emissions, which have partially been accounted for (e.g. cement and chemical industry) or excluded (e.g. limestone use in the steel industry).

Various bottom-up studies have found cost-effective potentials for energy efficiency improvement in the industrial sector (Interlaboratory Working Group, 1997; Energy Innovations, 1997). Many studies identified energy efficiency improvement opportunities. Innovative industrial technologies aim to not only reduce energy use, but also to improve productivity, reduce capital costs, reduce operation costs, improve reliability as well as reduce emissions and improve working conditions. Hence, many of the technologies discussed below will reduce the production cost of industries, and increase competitiveness in a globalizing economy.

We present scenarios for future industrial energy use, based on different assumptions for U.S. energy policies, using the results of the *Scenarios for a Clean Energy Future* (CEF) study (IWG, 2000). Following a 1997 study, *Scenarios of U.S. Carbon Reductions,* the U.S. Department of

Energy (US DOE) commissioned an Interlaboratory Working Group to examine the potential for public policies and programs to foster efficient and clean energy technology solutions to these energy-related challenges. The earlier report (Interlaboratory Working Group, 1997) identified a portfolio of technologies that could reduce carbon emissions in the United States to their 1990 levels by the year 2010. The CEF study identifies specific policies and programs that could motivate businesses to purchase the technologies making up its scenarios. A scenario is a way to understand the implications of a possible future through modeling assumptions that reflect this future. By definition, considerable uncertainties exist in all scenario analyses and this is also true for the industrial sector where ever-changing dynamics drive decision-making. Uncertainties in the assumptions affect the final results of the scenarios. However, as it is not always possible to quantitatively estimate the uncertainties and for reasons of presentation we only present point estimates.

We analyze two policy-driven scenarios using the CEF-NEMS model. The CEF-NEMS model does not allow direct modeling of demand side policies in the industrial sector. Hence, extensive changes were made to the model inputs to reflect the actions due to new policies in the policy scenarios, as outlined in the methodology section. The projected changes in inputs are based on analyses by industry, government and academic sources.

METHODOLOGY

For the analysis we used an adapted version of the U.S. Energy Information Administration's National Energy Modeling System (NEMS), which is used for EIA's energy forecasting.[1] In NEMS energy use can be modeled at the energy service demand, or process stage, level, while for other sectors no equipment is explicitly modeled nor are there any engineering links between process stages, and technology is represented parametrically. The CEF-NEMS Industrial Module contains no explicit equipment characterizations, but the parameters can be calculated based on assumptions of technology performance and penetration. These estimates are an exogenous input to the model. For the CEF policy scenarios, new inputs were developed for the CEF-NEMS model.

Business-As-Usual Scenario

In the CEF –study we adopted the economic scenarios as used by the EIA for the AEO99 as the business-as-usual scenario. We adopt the energy consumption data of the AEO99 reference case for the business-as-usual scenario for all industrial sub-sectors except for paper, cement, steel, and aluminum, the first three of which we analyzed in detail. For the paper, cement, and steel sectors, our estimates of physical energy intensities by process differed from those in used in the AEO99. We also changed the retirement rates for all sub-sectors to reflect actual lifetimes of installed equipment, based on detailed assessments of equipment ages and future developments in these sectors. Although NEMS does not treat equipment lifetime endogenously, it is possible to define the retirement rate for process equipment. Retirement rates for industrial technologies in the AEO99 scenario seem to be low, when compared to other sources (BEA, 1993; Jaccard and Willis, 1996), or assessments of technical and economic lifetimes of technologies. The modifications to the AOE99 reference case result in slightly lower CEF-NEMS business-as-usual energy consumption values compared to AEO99 (approximately 2% lower by 2020).

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1 We refer to our adapted version of the NEMS model as CEF-NEMS.

Policy Scenarios

We analyze two policy implementation scenarios – a moderate scenario based on establishment of voluntary agreements with industry that set moderate annual energy efficiency improvement commitments and an advanced scenario setting higher voluntary energy efficiency improvement commitments. The two policy scenarios assume successful implementation of a portfolio of policy measures to improve energy efficiency. Our analysis begins with an assessment of policies and programs applicable to the industrial sector. We use voluntary industrial sector agreements between industry and government as the key policy mechanism to attain energy efficiency improvements and to reduce greenhouse gas emissions. These voluntary industrial sector agreements are supported by a comprehensive package of policies and programs designed to encourage implementation of energy-efficient technologies and practices. Based on policy evaluations (ex-ante and ex-post) and different studies, we have estimated the effect of policy implementation on industrial technology choice and energy use. The effects of the different policies have been combined in an effort to model the impact of the policy portfolio. The impact has been modeled by using the model inputs as discussed above. It is not possible within this paper to discuss the individual inputs, hence the reader is referred to the CEF report for details (IWG, 2000).

Each industrial sub-sector was evaluated to determine the potential energy savings and GHG emissions reductions that result from implementation of the two policy scenarios. Since voluntary industrial sector agreements are the umbrella under which a number of policies and programs contribute to decisions to implement energy-efficient technologies and measures, it is often difficult to allocate specific actions to specific policies or programs. Estimates are made to allocate the overall synergetic effects of actions taken due the supporting policies and measures.

Actions Addressed Within CEF-NEMS

We determined where and how the energy savings might be achieved in terms of modeling parameters and modeled these changes in CEF-NEMS, on an aggregation level appropriate for the CEF-NEMS model. Some policies may affect only one modeling parameter. For example, research and development is most likely to affect the energy efficiency improvement and availability of new equipment. On the other hand, a carbon trading system will affect the price of energy and will likely influence all parameters of the model.

For **existing equipment** in the paper, cement, and steel sectors, modifications were made based on calculations made outside of CEF-NEMS. For the other sectors, we relied on recent analyses of the energy efficiency improvement potentials in these sectors or used the AEO99 HiTech Case inputs. The rate of adoption of **new energy-efficient technologies** and measures for new equipment is characterized in NEMS using TPCs. The TPCs were modified in the moderate and advanced scenarios in all sectors based on recent analyses of the energy efficiency improvement potentials (e.g. Worrell et al, 1999; Martin et al., 1999; Martin et al, 2000). Product labeling programs and pollution prevention programs will reduce primary **resources inputs** in the paper, glass, cement, steel, and aluminum subsectors as these industries move toward increased use of recycled materials. Material inputs in CEF-NEMS have been adjusted in the moderate and advanced scenarios to reflect such a shift, based on recent studies (e.g. Barnett, 1998; McLaren, 1997; PCA, 1997; Plunker, 1997) and technical limitations. Expanded Steam Challenge, expanded state programs, expanded Clean Air programs and SIPs, and expanded OIT R&D

programs will all contribute to improved **boiler efficiency**. Boilers in AEO99 are modeled with a set or fixed efficiency of around 80% for boilers using fossil fuels and 74% for by-product boilers. In reality boiler efficiency can vary widely, e.g. between 65% and 85% for coal boilers (CIBO, 1997). Also, in NEMS boilers are not retired, so the efficiency gains from new boilers are not captured in the model. Based on the assumptions in the BAU-scenario, and assessments of boiler efficiency improvements (CIBO, 1997; Einstein et al., 2001) we have determined improvement rates for the policy scenarios, reflecting the retirement of older boilers as well as the potential impact of the policy measures. Various programs will lead to improvements in **industrial building energy efficiency**. The NEMS model does not account for energy use in buildings in the agriculture, mining, or construction industries, but does include building energy use in all of the remaining industries. For these industries, we adopt the energy savings potential for the moderate and advanced scenarios identified in this study for commercial buildings.

Actions Addressed Outside CEF-NEMS

Various actions due to policies were modeled outside of CEF-NEMS, although some results were fed into the CEF-NEMS model. We assessed the potential impacts of policies on retrofitting existing technologies in the paper, cement, and steel industry, and two related cross-cutting opportunities, i.e. cogeneration (or combined heat and power, CHP) and motor systems. In the paper, cement, and steel **industrial sub-sectors** we assessed the technologies available to *retrofit* existing plants. In total, over one hundred technologies were characterized with respect to potential energy savings, costs, and potential degree of implementation. **Combined Heat and Power Production** (CHP) is modeled separately to model the interaction with the power sector, effects of policy initiatives, and the replacement of retired industrial boilers. The model allows the use of CHP for new steam generation capacity, due to growth of steam demand in the sectors. The NEMS model does not retire old boilers. Hence, brownfield applications of CHP can not be modeled inside the model, but are modeled outside the model. As growth in steam demand in most sectors is slow in the policy scenarios, implementation of CHP in the model itself is very limited. The CHP analysis was performed using Resource Dynamics Corporation's DISPERSE model[2]. The results were compared with results of studies using other utility models, i.e. the IPM model run for US EPA. DISPERSE is a model that compares on-site power generation with the grid on the basis of costs. DISPERSE estimates the achievable economic potential for CHP. The model not only determines whether on-site generation is more cost effective, but also which technology and size appears to be the most economic. As a result, double counting of market potential for a variety of competing technologies is avoided. It was not possible to fully integrate the DISPERSE results into CEF-NEMS[3]. Hence we were unable to assess the integrated impact on electricity generation and fuel mix.

Barriers and Policies

Industrial sector policies and programs are designed to address a number of barriers to investment in energy efficiency and greenhouse gas emissions reduction options including willingness to invest, information and transaction costs, profitability barriers, lack of skilled personnel, and other market barriers.

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[2] Distributed Power Economic Rationale Selection (DISPERSE) model.

[3] Within the timeframe of this study it proved to be impossible to model the cogeneration results into CEF-NEMS model at the industrial sub-sector level. Future work is needed to balance the boiler representation used in DISPERSE-model with steam demand in CEF-NEMS and to integrate the DISPERSE-results in the integrated CEF-NEMS scenarios to estimate impact on power sector energy demand and fuel-mix, as well as second order effects, due to changes in fuel mix and energy demand.

Voluntary sector agreements between government and industry are used as the key policy mechanism to reduce the barriers, while accounting for the characteristics of technologies, plant-specific conditions, and industrial sector business practices is needed. Policies and measures supporting these voluntary sector agreements should account for the diversity of the industrial sector while at the same time being flexible and comprehensive, offering a mix of policy instruments, giving the right incentives to the decision maker at the firm level, and providing the flexibility needed to implement industrial energy efficiency measures. Industry is extremely diverse, and even within one sub-sector large variations in the characteristics may be found. Various instruments which support the voluntary sector agreements, both at the federal level and state level, are put in place in the policy scenarios to reach the very diverse stakeholders.

Voluntary agreements (VAs) are "agreements between government and industry to facilitate voluntary actions with desirable social outcomes, which are encouraged by the government, to be undertaken by the participants, based on the participants' self-interest" (Story, 1996). A VA can be formulated in various ways; two common methods are those based on specified energy efficiency improvement targets and those based on specific energy use or carbon emissions reduction commitments. In this study, the VAs are defined as a commitment for an industrial partner or association to achieve a specified energy efficiency improvement potential over a defined period. The level of commitment, and hence specified goal, varies with the moderate and advanced scenario. The number and degree of supporting measures also varies with the two scenarios, where we expect the increased industrial commitment to be met with a similar increased support effort by the federal and state government. The effectiveness of VAs is still difficult to assess, due to the wide variety and as many are still underway. We estimate the effect on the basis of various efforts undertaken. VAs in Japan and Germany are examples of self-commitments, without specific support measures provided by the government. Industries promised to improve energy efficiency by 0.6% to 1.5% per year in those countries (IEA, 1997a). The VAs in The Netherlands have set an efficiency improvement goal of 2% per year (IEA, 1997b). Industries participating in the voluntary agreements in The Netherlands receive support by the government, in the form of subsidies for demonstration projects and other programs. The VAs were attractive to industry, as they allowed the development of a comprehensive approach, provided stability to the policy field, and were an alternative to future energy taxation (Van Ginkel and De Jong, 1995), or regulation through environmental permitting. For more details on VAs, see Worrell and Price (2001). Evaluation of voluntary industrial sector agreements in The Netherlands showed that the agreements helped industries to focus attention on energy efficiency and find low-cost options within commonly used investment criteria. Experience with industrial sector VAs exists in the U.S. for the abatement of CFC and non-CO_2 GHG emissions. For example, eleven of twelve primary aluminum smelting industries in the U.S. have signed the Voluntary Aluminum Industrial Partnership (VAIP) with EPA to reduce perfluorocarbon (PFC) emissions from the electrolysis process by almost 40% by the year 2000. Similar programs exist with the other industries.

Table 1 outlines the various policies and programs. These include expansion of a number of existing programs as well as establishment of new programs. The effects of increased program efforts are difficult to assess. Cost-effectiveness may improve due the increased volume, but may also be less effective as programs reach smaller energy users or lead to implementation of less-effective measures. The interaction of various measures deployed simultaneously is difficult to estimate ex-ante, or even ex-poste (Blok, 1993). It is also often more difficult to assess the impacts of individual programs than the estimated impact of a set of policies.

Table 1. Policies and Programs for Reducing Energy Use and Greenhouse Gas Emissions from the Industrial Sector Under the Moderate and Advanced Scenarios

Policy/Program	Moderate Scenario	Advanced Scenario
Voluntary Industrial Sector Agreements		
Voluntary Industrial Sector Agreements	Voluntary programs to reduce GHG emissions in energy-intensive and GHG-intensive industries, for specific industrial process or buildings.	Voluntary programs to reduce GHG emissions (CO_2 and non-CO_2) in all industries, including benchmarking.
Voluntary Programs		
Expanded Challenge programs Motor and Compressed Air Challenge	Increased effort to assist in motor system optimization through increased education, technical assistance, training, and tools. Increased promotion of adjustable-speed drives.	Increased promotion of motor system efficiency and use of adjustable-speed drives by offering greater financial incentives.
Steam Challenge	Outreach, training, and development of assessment tools is increased.	Expanded to include outreach to smaller boiler users and to develop automated monitoring and controls.
CHP Challenge	Financial incentives, utility programs promoting CHP, and expanded removal of barriers (e.g. permitting) are added.	Program expands to include increased outreach, dissemination, and clearing-house activities
Expanded ENERGY STAR Buildings and Green Lights	Development of best practices management tools and benchmarking information. Floorspace covered by program increases by 50%.	Best practices management tools and benchmarking information expanded and more extensively marketed. Floorspace covered by program increases by 100%.
Expanded ENERGY STAR and Climate Wise program	Increased and program expansion to include glass, steel, and aluminum, as well as selected light industries.	Program expanded to include light industries, agriculture, construction, and mining.
Expanded Pollution Prevention Programs	Expanded effort leads to increased recycling in the steel, aluminum, paper, and glass industries.	Number of partners grows to 1600 by 2020 (from 700 in 1997).
Information Programs		
Expanded Assessment Programs	Number of industrial assessment centers increases to 35 and number of assessments per center increases. Expanded to include business schools and community colleges. Added emphasis on increased follow-up.	Number of industrial assessment centers increases to 50 and number of assessments per center increases to 40 per year. Comprehensive energy plans for each audited facility added.
Product Labeling and Procurement	Development of labels for two products.	Labeling expanded to other products (e.g. glass bottles). Marketing of labels is increased and government procurement policies are revised to include labeled products.
Investment Enabling Programs		
Expanded State Programs State Industrial Energy Efficiency Programs	Current state level programs are expanded. Participation grows from less than half of the states to 30 states.	Programs expanded to include all 50 states.
Clean Air Partnership Fund	Expanded use of integrated approaches for complying with CAA. Expanded demonstration of new technologies.	GHG emissions reduction projects given higher priority.

Expanded ESCO/utility programs Standard performance contracting (line charge)	Expansion of line charges to 30 states and increased efforts to target small industrial customers.	Expansion of line charges to 50 states and further increased efforts to target small industrial customers.
Financial incentives Tax incentives for energy managers	Provides tax rebates of 50% of the salary of an energy manager to 5000 medium and large energy-using industries by 2020.	Tax rebates provided to 10,000 medium and large energy using-industries by 2020.
Tax rebates for specific industrial technologies	Increased rebates focus on implementation of advanced technologies.	Increased rebates focus on implementation of advanced technologies. Increased funding leads to accelerated adoption of these technologies.
Investment tax credit for CHP systems	Tax credit extended from 2003 to 2020, leading to expansion of CHP as well as third party producers at industrial sites.	Tax credit extended from 2003 to 2020, leading to expansion of CHP as well as third party producers at industrial sites.
Regulations		
Motors Standards and Certification	Mandates upgrade of all motors to EPACT standards by 2020. Promote national motor repair standard.	Extends standards to all motor systems and enforces 100% compliance. Mandates national motor repair standard.
State Implementation Plans/Clean Air Partnership Fund	Identifies control measures and regulations to adopt and enforce the control strategies.	Identifies control measures and regulations to adopt and enforce the control strategies.
Research & Development Programs		
Expanded Demonstration Programs	Demonstration programs expanded in currently addressed sectors and extended to mining and construction sectors. Number of demonstration programs increased from 10 to 15 per year.	Extent of demonstration programs further expanded in all sectors and incorporated into state demonstration programs. Number of demonstration programs increases to 18 per year.
Expanded R&D programs Industries of the Future	Increased R&D efforts in all industries currently in program.	Increased R&D efforts in all industries currently in program and expansion to a number of smaller "other manufacturing" industries.
Other OIT R&D programs	Program R&D efforts increased in all areas related to improving industrial sector energy efficiency.	Industrial sector energy efficiency R&D efforts further increased.
Domestic Carbon Dioxide Emissions Trading System	N/A	

Scenario Results

Generally, a number of cross-cutting technologies can achieve large improvements, e.g. preventative maintenance, pollution prevention and waste recycling, process control and management, steam distribution system upgrades, improved energy recovery, cogeneration (CHP), and drive system improvements. However, a large share of the efficiency improvements is achieved by retiring old process equipment and replacing it with state-of-the-art equipment (Steinmeyer, 1997). This emphasizes the need for flexibility in achieving energy efficiency improvement targets, as provided by the voluntary industrial agreements.

Energy savings are found in *all industrial sub-sectors*. Production growth is lower in most energy-intensive industries than the less energy-intensive manufacturing industries. Hence, most of the growth in energy use and emissions can be found in the light industries. Energy efficiency improvements in the policy scenarios appear high, as the improvements in the baseline scenario are almost zero in the light industries. While light industries would consume almost half of the energy by 2020 in the reference scenario, almost 50% of the total energy savings in the advanced scenario are also found in these industries.

The characteristics of decision makers vary widely. Hence, there is no “silver bullet” policy; instead, an integrated policy accounting for the characteristics of technologies and target groups is needed. Acknowledging the differences between individual industries (even within one economic sector) is essential to develop an integrated policy. Policies and measures accounting for the diversity of industry, offer a mix of policy instruments, give the right incentives to the decision maker at the firm level, and provide flexibility needed to implement industrial energy efficiency measures.

In the **reference scenario** industrial energy use grows from 34.8 Quads in 1997 to 41.0 Quads in 2020, which is almost equal to that of the AEO99 (42.1 Quads), see Figure 1. Energy use in the reference scenario shows a slight growth of 0.7%/year, while industrial output grows by almost 1.9%/year. Hence, the aggregate industrial energy intensity decreases by about 1.1%/year, or 23% over the scenario period. The intensity change in the AEO99 scenario is due to inter-sector structural change (almost three-fourths of the change), i.e. a shift to less energy intensive industries, and energy efficiency improvement (about one fourth). Carbon dioxide emissions from the industrial sector in the reference scenario increase by nearly 0.7%/year to 578 MtC. The growth in the reference scenario can be found in other manufacturing industries (e.g. metals based durables, other manufacturing) and the non-manufacturing industries. Energy use in the energy intensive industries grows slightly, or is even reduced, due to slower economic growth in these sectors, resulting in the inter-sector structural change of the economy. By 2020, energy intensive industries still consume 51% of total industrial energy use, down from 55% in 1997. The industrial fuel-mix changes slightly towards less carbon-intensive fuels.

In the **moderate scenario** industrial energy use grows from 34.8 Quads in 1997 to 37.9 Quads in 2020, equivalent to a growth of 0.4%/year (excluding CHP). Total industrial energy use in 2020 under the moderate scenario is about 8% lower than the reference scenario. In the moderate scenario overall industry energy intensity falls by 1.5%/year. Annual carbon emissions are increasing to approximately 521 MtC, or a reduction of 10%. The changes in carbon intensity are larger due to the shift towards lower carbon fuels and intra-sectoral structure changes. Under the policies in the moderate scenario the light non-energy intensive industries will remain the largest contributors to future growth in energy demand. The high growth in the reference scenario is offset by efficiency improvements (approximately 0.4%/year) in those industries under the moderate scenario. The overall fuel-mix in industry is changing more rapidly to low carbon fuels, when compared to the reference scenario. By 2020 natural gas will provide almost a third of the primary energy needs of the total industry. Energy service costs, including annual fuel costs, annualized incremental technology cost of energy efficiency improvement, and annual program costs to promote energy efficiency, decrease by approximately 9% by 2010 and 10% by 2020, relative to the reference scenario.

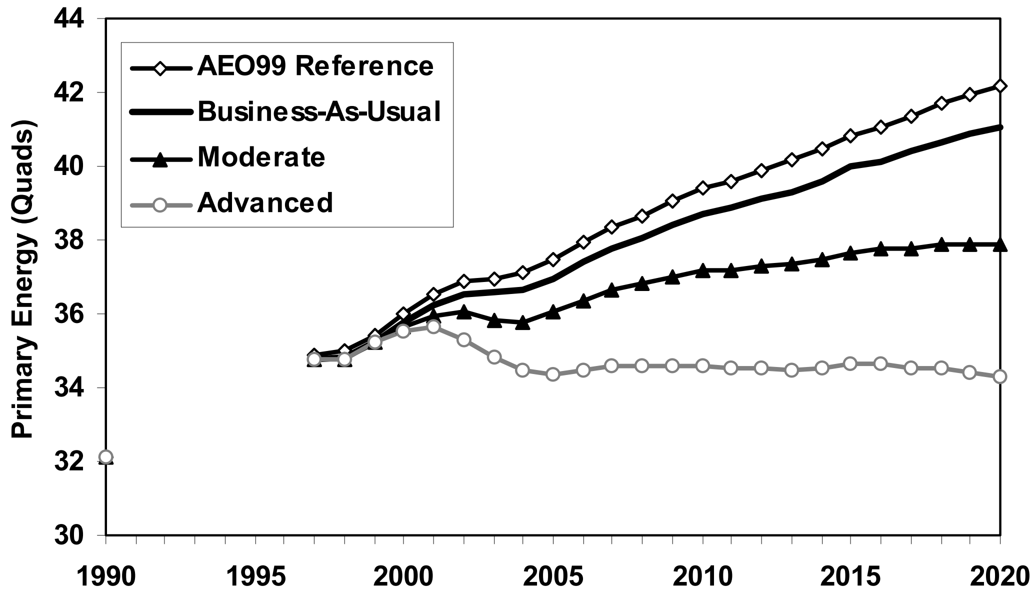

Figure 1. Scenario results for primary industrial energy use in U.S. industry.

Table 2 Primary Energy Intensity Development in CEF-NEMS Scenarios.

Economic Intensities (MBtu/$-output (1987-$) on a primary energy basis							
Scenario		Business-as-Usual		Moderate		Advanced	
Sector	1997	2010	2020	2010	2020	2010	2020
Refining	23.6	26.7	25.3	26.2	23.7	24.1	19.3
Food	4.3	3.9	3.7	3.8	3.6	3.5	3.3
Pulp & Paper	28.0	23.7	22.1	23.1	21.4	21.1	20.7
Bulk Chemicals	32.2	28.9	27.6	27.5	25.3	24.5	22.1
Glass	13.1	11.5	10.6	11.5	10.5	9.9	9.0
Cement	97.7	89.4	84.5	87.1	79.5	78.6	67.6
Iron & Steel	30.1	24.0	21.9	23.3	20.6	20.6	18.6
Aluminum	23.3	19.2	17.3	18.5	16.6	16.2	14.7
Agriculture	5.2	5.0	4.9	4.8	4.5	4.6	4.0
Construction	5.1	4.9	4.7	4.6	4.3	4.5	4.1
Mining	21.4	22.1	22.4	20.8	20.2	20.3	19.2
Metal Durables	2.0	1.8	1.6	1.7	1.5	1.5	1.3
Other Manufacturing	5.5	5.1	4.8	4.9	4.4	4.6	3.9
Total	8.7	7.4	6.7	7.1	6.2	6.6	5.6
Physical Intensities (MBtu/ton) on a primary energy basis							
Pulp & paper	33.9	28.4	26.4	27.8	25.6	25.4	24.7
Glass	17.2	15.2	14.1	15.2	14.0	13.1	12.1
Cement	4.7	4.6	4.0	4.1	3.8	3.7	3.2
Iron & Steel	20.2	18.2	14.5	15.5	14.3	13.7	12.3
Aluminum	125.3	105.7	93.1	99.1	87.4	86.9	79.0

* Bulk chemicals excludes feedstocks. The increased contribution of CHP is excluded in this analysis.

In the **advanced scenario** a stronger push to improve energy efficiency will result in an active policy for energy efficiency improvement and GHG emission reduction. In the advanced scenario industrial energy use remains stable, decreasing from 34.8 Quads in 1997 to approximately 34.2 Quads in 2020 (excluding CHP). Total industrial energy use in 2020 under the advanced scenario is 16.5% lower than the reference scenario. Under the conditions in the advanced scenario overall industry energy intensity falls by 1.8% per year (see Table 2), of which 1.0% per year due to energy efficiency improvement. This compares well to the experiences in other countries that VAs can potentially contribute an efficiency improvement of 0.4% to 1.3% per year. Carbon emissions are actually decreasing to approximately 409 MtC, or a reduction of 29% relative to the reference scenario, especially due to de-carbonization in the power sector. While increased CHP in industry is expected to impact the observed shift to natural gas, the CHP results have not yet been integrated in the current fuel-mix shift. Annual energy service costs in the advanced scenario are reduced by 8% in 2010 and by 12% by 2020, translating to cost savings of approximately $8 Billion and $14 Billion respectively. The savings are significantly higher in 2020 than in 2010, due to the larger investments in energy R&D in the advanced scenario, which results in greater energy savings on the long term.

Cogeneration

The results of the CHP calculations could not be integrated in the CEF-NEMS framework. Instead, we estimate the potential impact using the DISPERSE model. These estimates include both traditional, non-traditional applications of CHP, and is limited to industrial sector applications (hence, it excludes distributed CHP or district heating). In the **BAU scenario**, 8.8 GW of new CHP is projected, based on a continuation of current market penetration trends. Several technical and market barriers stand in the way of further use of CHP, as evidenced by the fact that over 80 percent of the potential capacity is projected as untapped. Most potential for CHP can be found in the paper, chemical, food and the non-energy-intensive manufacturing sectors. In the **moderate scenario**, the projected additional CHP-capacity grows to approximately 14 GW by 2010 and 40 GW by 2020. The net impact in 2020 is an energy saving of 0.53 EJ and a reduction in carbon dioxide emissions of 9.7 MtC. In the **advanced scenario**, the projected level of new CHP reaches approximately 29 GW by 2010 and 76 GW by 2020. The net impact in 2020 is an energy savings of 2.5 EJ and a reduction in carbon dioxide emissions of 39.7 MtC.

FUTURE ANALYSIS NEEDS

This study highlights various issues for future research related to modeling and policies. The available resources limited a quantitative analysis of the uncertainties in scenarios. Hence, future analysis aims not only at areas that need further analysis, but also at assessing the uncertainties in the scenarios. The analysis needs to include improved capabilities and tools to model policy impacts, improved modeling of CHP and steam system representation in industrial modeling, and a better understanding of retirement rates due to its important effect on energy use.

Detailed evaluations of industrial energy efficiency policies are rare (Martin et al., 1998; US DOE, 1996). Analysis of the effects and effectiveness of industrial energy policies is needed. Industrial technology development is often aimed at improving productivity rather than improving energy efficiency, and research is needed to better quantify the other benefits of energy efficiency measures. Other topics for future research include the role of business cycles, improved understanding of technology diffusion, and the role of integrating other non-CO_2 GHGs in the assessment of emission reduction strategies for industry.

Conclusions & Summary

Industrial primary energy consumption is estimated at 34.9 Quads, or 37% of total primary energy use in the U.S. in 1997. We have investigated two policy scenarios, assuming successful implementation of a portfolio of policy measures to improve energy efficiency. Under the business-as-usual scenario industrial energy consumption would grow to 41 Quads in 2020. Under the moderate scenario, total energy use would be 38 Quads in 2020 (-7%), while in the advanced scenario total energy use would be 34 Quads (-17%). Carbon dioxide emissions would grow to 578 MtC by 2020 under the BAU-scenario, approximately 521 MtC (-10%) under the moderate, and 409 MtC (-29%) under the advanced scenario. This compares to estimated 1990 emissions of 452 MtC in industry. These figures exclude the contribution of CHP. Energy efficiency opportunities are found throughout the industry. The characteristics of decision-makers vary widely. Therefore, an integrated policy framework accounting for the different characteristics of decision-makers, technologies and sectors is necessary.

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